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OPERATION CASTLE

Project 2.7
Distribution of Radioactive Fallout By Survey and Analyses of Sea Water

March-May 1954

Headquarters Field Command
Armed Forces Special Weapons Project
Sandia Base, Albuquerque, New Mexico

April 14, 1959

NOTICE

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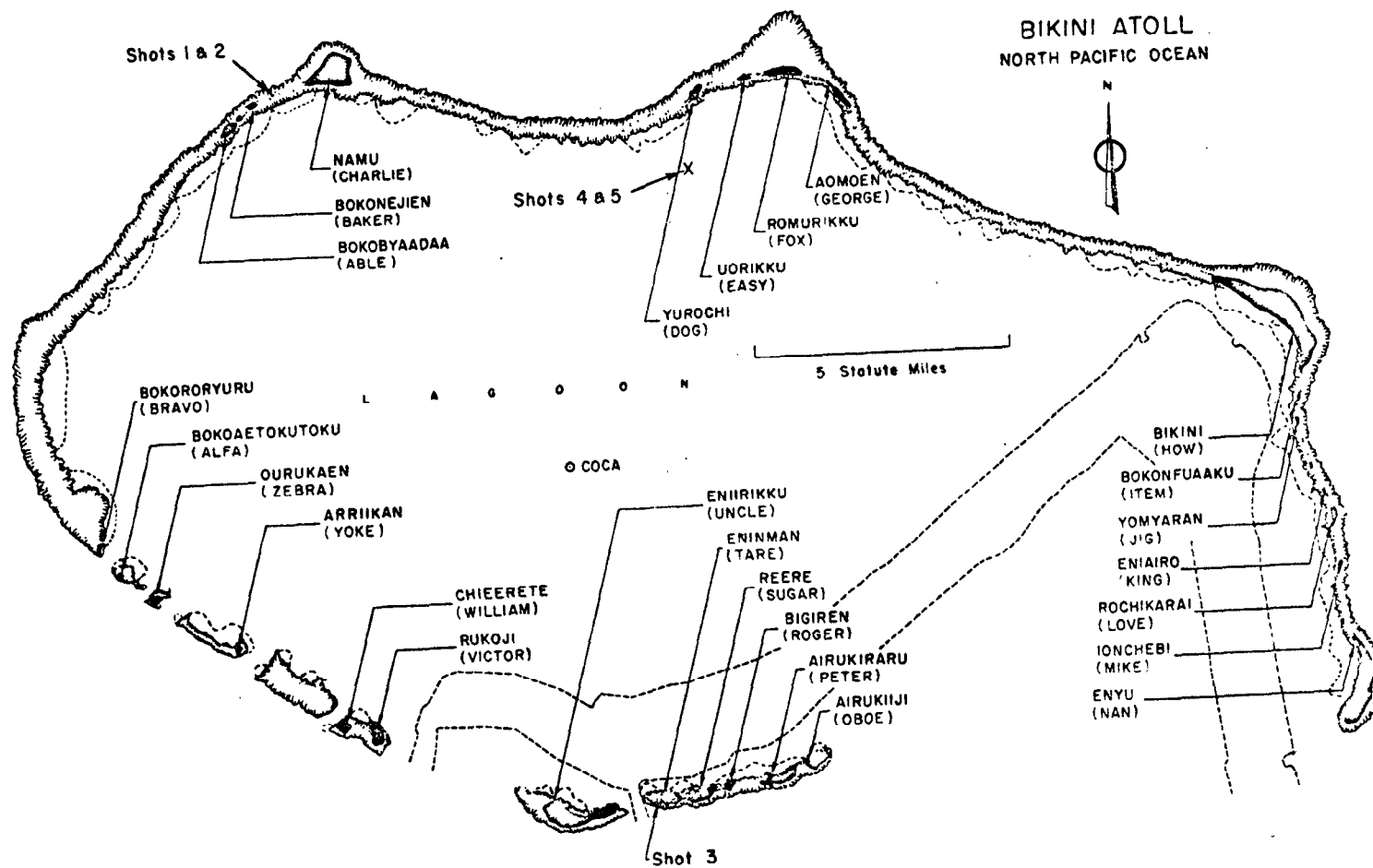
Extract version prepared for:

Director
DEFENSE NUCLEAR AGENCY
Washington, D.C. 20305

1 April 1981

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER WT-935 (EX)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Operation CASTLE - Project 2.7 Distribution of Radioactive Fallout by Survey and Analyses of Sea Water		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER WT-935 (EX)
7. AUTHOR(s) T. R. Folsom L. B. Werner		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Headquarters Field Command Armed Forces Special Weapons Project Sandia Base, Albuquerque, New Mexico		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE April 14, 1959
		13. NUMBER OF PAGES 89
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, If different from Report)

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Operation CASTLE
Radioactive Fallout
Radiation Measurements
Water Sampling

20. ABSTRACT (Continue on reverse side If necessary and Identify by block number)

ENIWETOK ATOLL
NORTH PACIFIC OCEAN

BIKINI ATOLL
NORTH PACIFIC OCEAN
N

Shots 1 & 2

NAMU
(CHARLIE)

BOKONEJIEN
(BAKER)

BOKOBYAADAA
(ABLE)

Shots 4 & 5

X

AOMOEN
(GEORGE)

ROMURIKKU
(FOX)

UORIKKU
(EASY)

YUROCHI
(DOG)

5 Statute Miles

BOKORORYURU
(BRAVO)

L   A   G   O   O   N

BOKOAETOKUTOKU
(ALFA)

OURUKAEN
(ZEBRA)

ARRIIKAN
(YOKE)

○ COCA

ENIIRIKKU
(UNCLE)

ENINMAN
(TARE)

REERE
(SUGAR)

CHIEERETE
(WILLIAM)

BIGIREN
(ROGER)

RUKOJI
(VICTOR)

AIRUKIRARU
(PETER)

AIRUKIIJI
(OBOE)

BIKINI
(HOW)

BOKONFUAAKU
(ITEM)

YOMYARAN
(JIG)

ENIAIRO
(KING)

ROCHIKARAI
(LOVE)

IONCHEBI
(MIKE)

ENYU
(NAN)

Shot 3

5

GENERAL SHOT INFORMATION

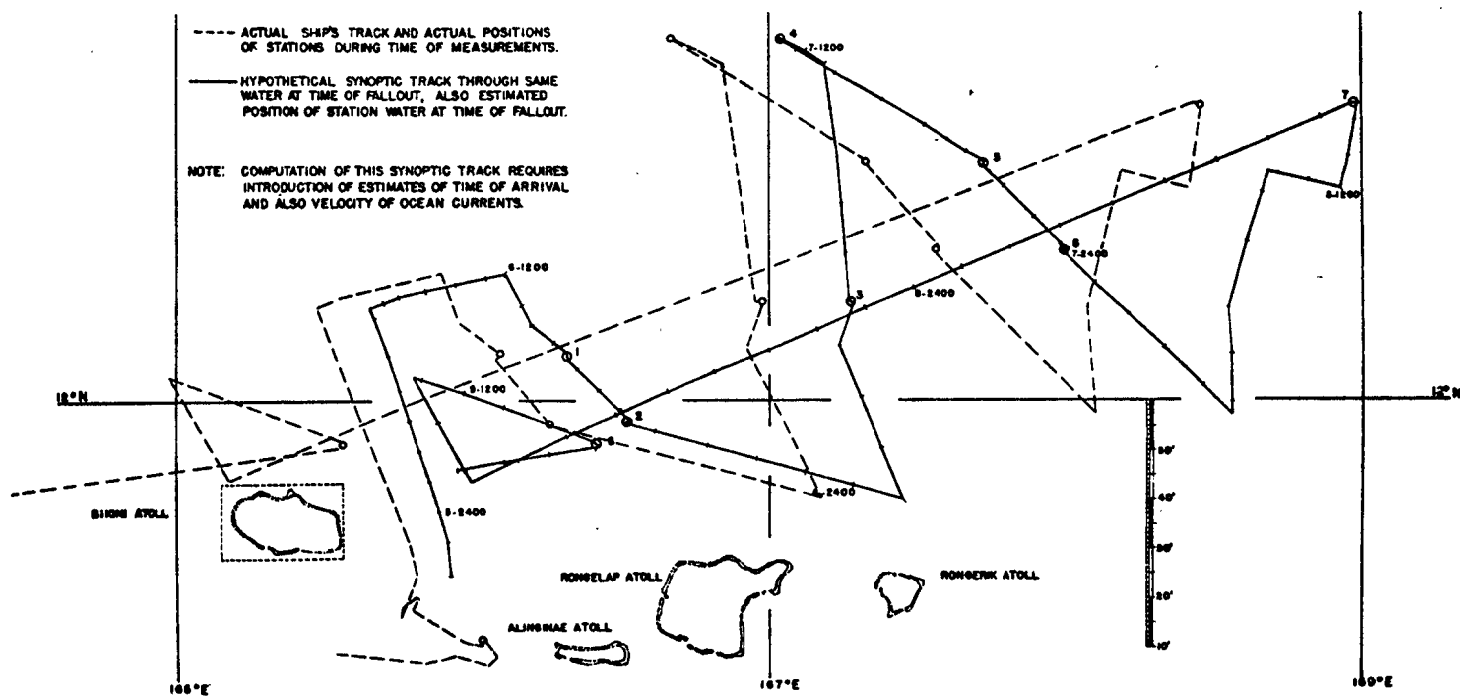|	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6
DATE	1 March	27 March	7 April	26 April	5 May	14 May
CODE NAME (Unclassified)	Bravo	Romeo	Koon	Union	Yankee	Nectar
TIME*	06:40	06:25	06:15	06:05	06:05	06:15
LOCATION	Bikini, West of Charlie (Namu) on Reef	Bikini, Shot 1 Crater	Bikini, Tare (Eninman)	Bikini, on Barge at Intersection of Arcs with Radii of 6900' from Dog (Yurochi) and 3 Statute Miles from Fox (Aomoen).		Eniwetok, IVY Mike Crater, Flora (Elugelab)
TYPE	Land	Barge	Land	Barge	Barge	Barge
HOLMES & NARVER COORDINATES	N 170,617.17 E 76,163.98	N 170,635.05 E 75,950.46	N 100,154.50 E 109,799.00	N 161,698.83 E 116,800.27	N 161,424.43 E 116,688,15	N 147,750.00 E 67,790.00

* APPROXIMATE

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ACTUAL SHIP'S TRACK AND ACTUAL POSITIONS
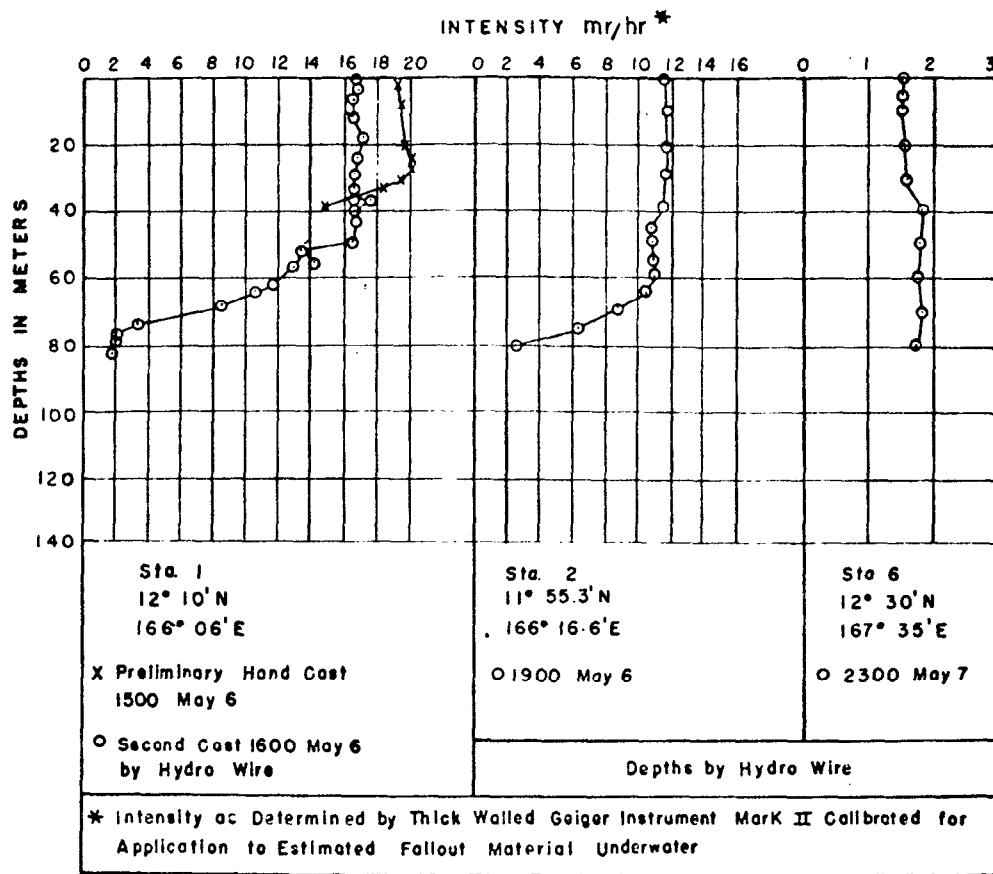OF STATIONS DURING TIME OF MEASUREMENTS.

HYPOTHETICAL SYNOPTIC TRACK THROUGH SAME
WATER AT TIME OF FALLOUT, ALSO ESTIMATED
POSITION OF STATION WATER AT TIME OF FALLOUT.

NOTE: COMPUTATION OF THIS SYNOPTIC TRACK REQUIRES
INTRODUCTION OF ESTIMATES OF TIME OF ARRIVAL
AND ALSO VELOCITY OF OCEAN CURRENTS.

Figure 2.6 Ship's track, Shot 5 survey.

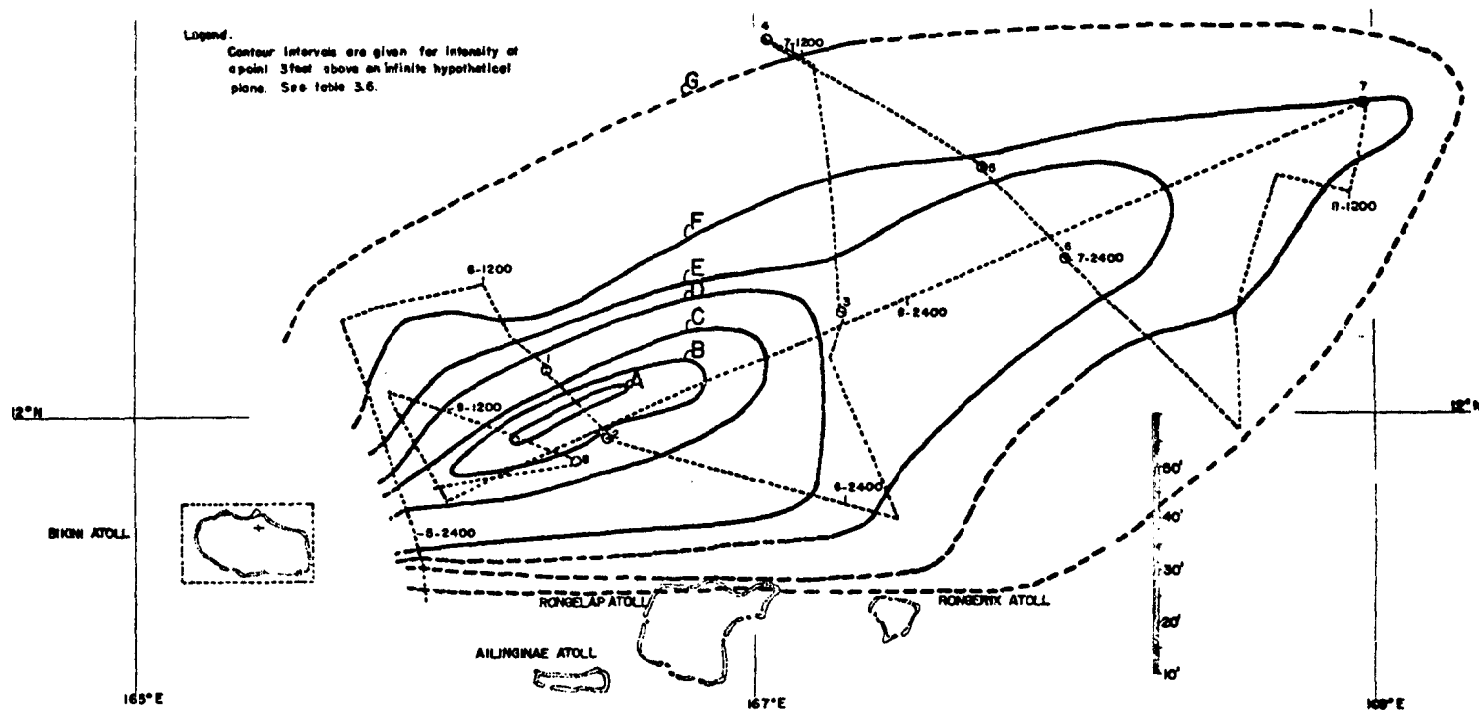Figure 3.4 Mark II vertical radioactivity profiles, Shot 5.
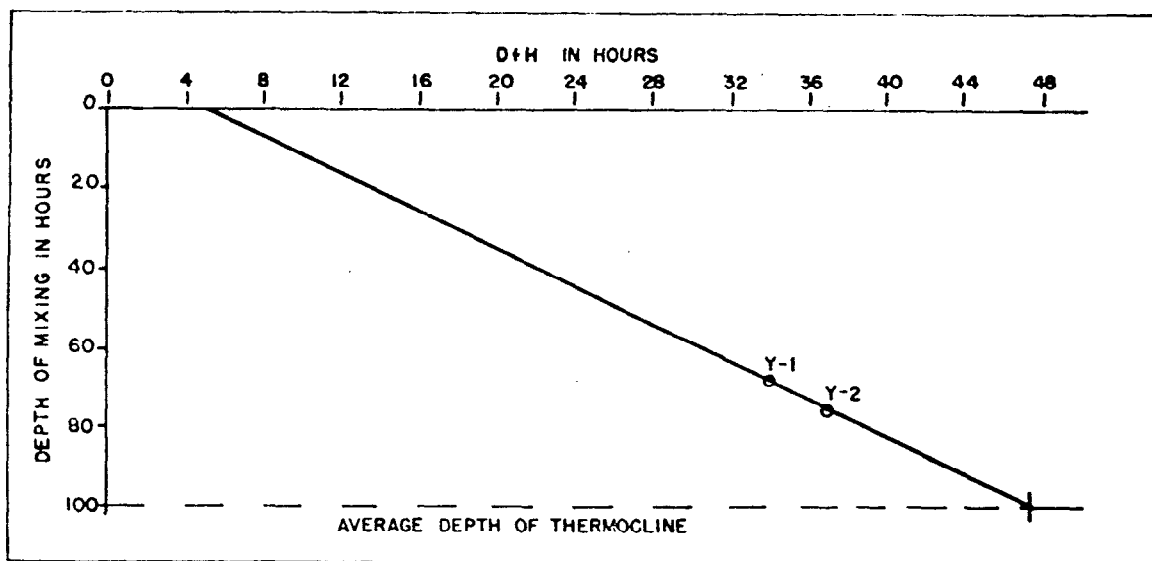
Figure 3.5 Progress of vertical mixing.
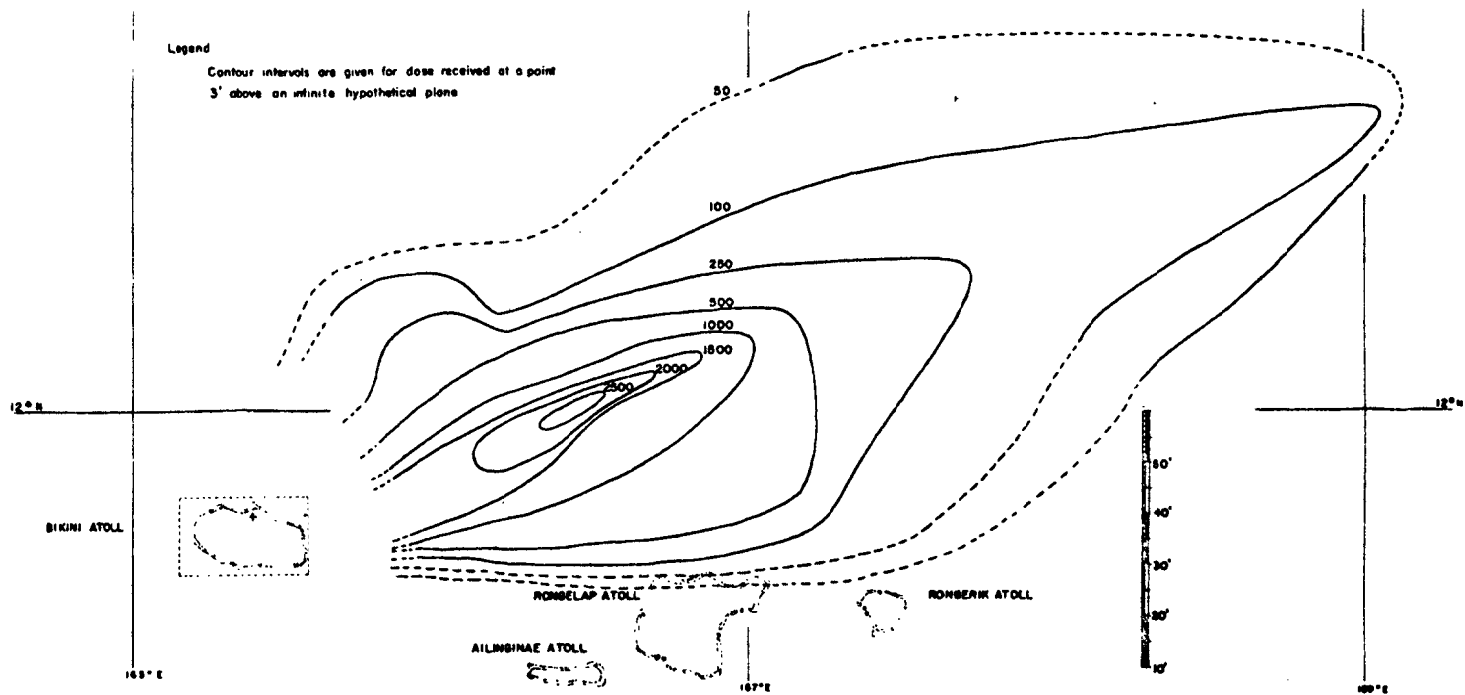
Figure 3.11 Iso-intensity contours for Shot 5.

Figure 3.12 Total dose from time of fallout to H + 50 hours in roentgens, Shot 5.

Table 3.6 Iso-dose Rate Contours at 3 Foot Elevation

Contour No.	Area (Sq. Miles)	Dose Rate (R/HR)	
		At H + 12 Hrs.	At H + 1 hr. = 22.7 x H + 12
A	45	80	1820
B	450	60	1360
C	1,190	40	910
D	3,070	20	450
E	6,320	10	230
F	10,000	5	115
G	17,850	1	25

Table 3.7 Total Dose from Fallout Arrival Until H + 50 Hours

Contour No.	Area (Sq. Miles)	Total Dose in R (Shown in Figure Itself)
Innermost	32	2500
-	210	2000
-	610	1500
-	1,400	1000
-	3,000	500
-	4,900	250
-	9,350	100
Outermost	14,350	50

induced activities. The curves are shown in Figures 4.1 and 4.5.

From these curves the dose rate at H + 12 hr d_{12} for Shot 5 is:

$$d_{12} = 5.58 \times 27.4 \times 10^{-7} \text{ A roentgens hr}^{-1}$$
$$= 1.53 \times 10^{-5} \text{ A roentgens hr}^{-1}$$

and for Shot 6:

$$d_{12} = 5.63 \times 15.7 \times 10^{-7} \text{ A roentgens hr}^{-1}$$
$$= 8.85 \times 10^{-6} \text{ A roentgens hr}^{-1}$$
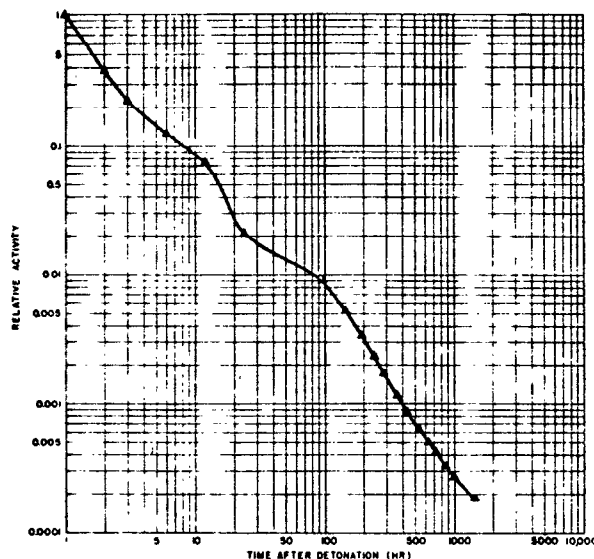

Figure 4.5 Calculated decay (d/m) for Shot 5 fallout.

Results for Shots 5 and 6 are tabulated in Tables 4.6 and 4.7 respectively.[7]

In view of the close agreement between these results for Shot 5 and those calculated independently from the water survey data (Chapter 3), contours for the water sampling results have not been drawn. Instead a comparison of the two sets of data is shown in Table 5.1.

Shot 6 results were plotted and contours drawn as shown in Figure 4.6. Aerial survey data (Reference 8) taken at H + 13 to H + 17 hours (Able flight) and H + 25 to H + 32 hours (Baker flight) were used as a rough aid in constructing contours, especially in areas where no water samples were taken. Relative intensities were read from aerial survey traces. Locations where aerial survey data and water sampling data coincide were used to normalize approximately the aerial survey traces to dose rate values calculated from water sample data. Drift corrections were applied to the latter. Baker flight traces were arbitrarily shifted 6 miles north and 6 miles east to improve the fit with Able flight and water sample data. The shift may be justifiable on the basis of errors in drift correction and position determinations. No depth of mixing calculations were made for the aerial survey data. Contours across the lagoon area were taken from Project 2.5a data (Reference 4).

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[7] In this report no attempt has been made to apply a "terrain factor" to the calculated results to approximate more closely the dose rates which would have been observed over a real land area. A terrain factor has not been estimated for PPG site conditions. Ksanda (Reference 7) has estimated for Operation Jangle fallout area at NTS that observed dose rates = 0.6 × calculated dose rates.
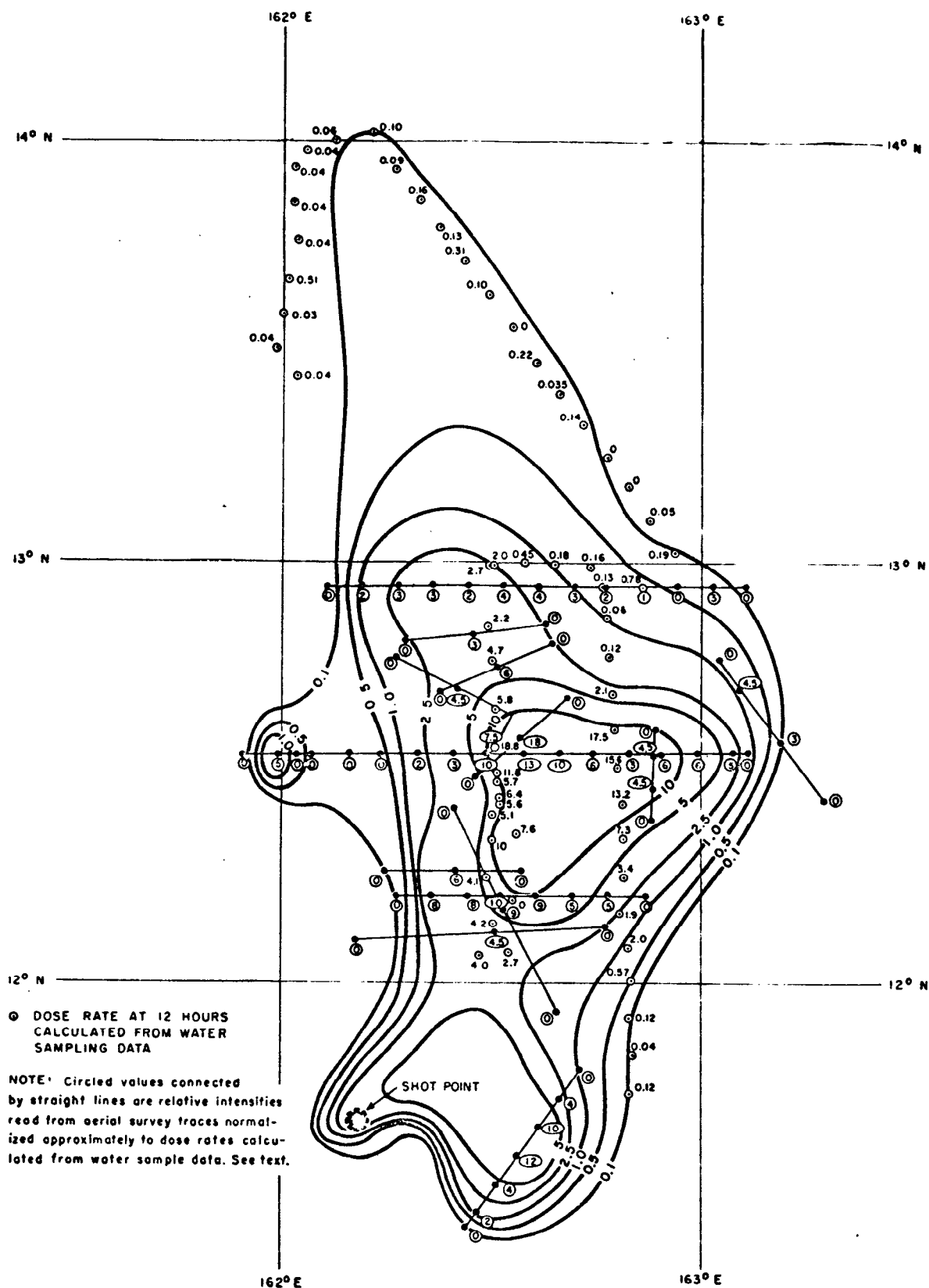
Figure 4.6 Estimated fallout dose rate contours for Shot 6 at H + 12 hours (r/hr).

Appendix A

COMPARISON OF COMPUTED DOSE RATE OVER THE SEA WITH CERTAIN ACTUAL MEASUREMENTS

A few measurements were made on deck and on the bridge while underwater dosages were being obtained following Shot 5. Intercomparison of these data permits a rough test of the familiar elementary theory for making predictions of dose rate above the sea from measurements made by submerged instruments. The behavior of the several instruments can be compared also.

Figure A.1 shows the manner in which these particular measurements were made, and Table A.1 lists the measurements and also their values after being reduced to dosage rates by application of suitable calibration curves.

Column 9 is the ratio of the intensity in air to the intensity underwater-measured by the same instrument, Mark II. Column 10 is the ratio of intensity in air measured by the ship's radiac set (type AN/PDR-27C) to the intensity underwater, measured by the Mark I device.

Column 11 is the ratio which was computed by using the simplified theory summarized in Equation D.4.3, page 435 of "The Effects of Atomic Weapons" (1950, LASL), under the assumption of monochromatic
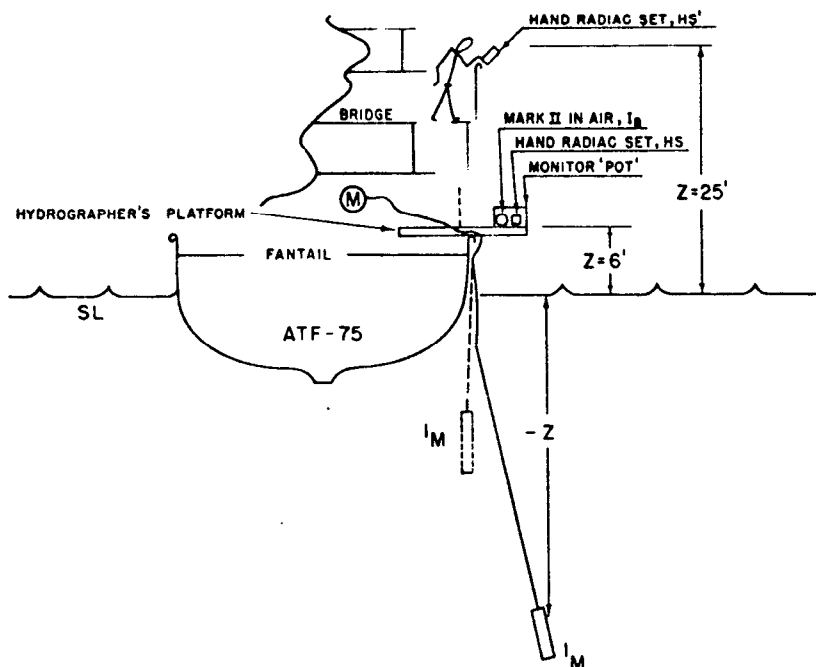

Figure A.1 Location of instruments during Shot 5. Surveys used for comparisons discussed in Appendix A.

energy of 0.7 Mev. This equation is not strictly accurate for a volume distributed source since it assumes angular distribution of unscattered radiation coming up from the water to be the same as for a plane source. However, this deficiency leads to smaller numerical error than arises from the neglect of scattered rays. It is recognized that this simple theory is deficient; there is an additional contribution due to scattering and the actual geometry including the ship cannot be treated properly.

Comparison may be made between Column 11 and Columns 9 and 10; the theoretical values agree with the experimental much better than might have been hoped for considering the geometric complications introduced by the presence of the ship. The ship filters rays coming from almost half the sea, but this is somewhat compensated for by the presence of local contamination on the deck and hull.

Table ʌ.1   Above Surface and Below Surface Survey Data and Their Ratios

Shot 5 Station Number	Time/Date	Elevation in feet	Underwater I_M		Air I_B		H_S	Experimental Ratios		Theoretical Ratios
			μa	mr/hr μa	mr/hr	mr/hr	mr/hr	I_B/I_M	HS/I_M	
Y - 1	1600/May 6	6	24.0*	16.9	11.0*	6.9		.40		.34
Y - 2	1900/May 6	6	17.5*	11.7	9.0*	5.4		.46		.34
On course	1621/May 6	6	15.0**	33.0			13.0		.39	.34
On course	1638/May 6	6	17.0**	51.0			21.0		.41	.34
On course	2315/May 5	25	21.0**	80.0			22.0		.27	.20
Column No. 1	2	3	4	5	6	7	8	9	10	11

Footnotes

* Mark II readings
** Mark I readings

Column No.

1. Location of measurement.
2. Time and Date of Measurement.
3. Elevation.
4. Meter Readings of Underwater Instrument.
5. Apparent mr/hr from Calibration Data Pertaining to Estimated Mixed Radiation Spectrum.
6. Meter Readings from Mark II in Air (on Hydro Platform).
7. Apparent mr/hr from Calibration for Estimated Mixed Radiation.
8. Meter Readings of Hand Set in mr/hr.
9. Experimental Ratios of $I_B:I_M$.
10. Experimental Ratios of $HS:I_M$.
11. Theoretical Ratios Based on Equation D.4.3 p. 435 in The Effects of Atomic Weapons (1950, LASL).